

No observations have been made or seem to be practicable for determining the actual rise of water within a hurricane on the open ocean. The rise observed at seaports when a hurricane passes near is due principally to the wind and tide, of which an example is given in the diagram exhibited by Gen. E. P. Alexander in the MONTHLY WEATHER REVIEW for May, 1896, who uses the term "tidal wave" or "storm tide" or "storm wave" as representing the total effect of the storm on the water, and, therefore, quite in accord with our definition No. 5.

It is earnestly to be desired that observers learn to distinguish between tidal waves and storm waves. Blanford describes a typical tidal wave under the name of *bore*. (See page 461.)

As has already been pointed out,¹ most of the so-called tidal waves are really storm waves.

Severe waves often accompany earthquakes, as was the case in Lisbon in 1755 and in Japan in 1895; these are not tidal waves, but may be called *earthquake waves*.—H. H. K.

ON BAROMETRIC OSCILLATIONS DURING THUNDERSTORMS, AND ON THE BRONTOMETER, AN INSTRUMENT DESIGNED TO FACILITATE THEIR STUDY.*

By G. J. SYMONS, F. R. S.

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The fact that a rise of the barometer occurs during thunderstorms has been supposed by many to be newly discovered through the general establishment of self-recording barometers; but Dr. Hellmann has shown that it was noticed by J. J. Planer as far back as 1782. In 1784, Rosenthal epitomised the facts as follows: "When a thunderstorm approaches the place where a barometer is situated, the mercury in the tube begins to rise; the nearer the thunder cloud comes to the zenith of the observer, the higher does the mercury rise, and it reaches its highest point when the storm is at the least distance from the observer. As soon, however, as the cloud has passed the zenith, or has become more distant from the observer, the weight of the atmosphere begins to decrease and the mercury to fall." A few years later, Toaldo determined the amount of the rise in several storms, and found it to be between 1 and 2 lines (0.09 inch to 0.18 inch).

Professor Strehlke (in 1827-1830) made several sets of observations, and found the rise to be from 0.04 inch to 0.06 inch, and was probably the first to point out that the highest point of the barometer is not absolutely synchronous with the passage of the center of the storm-cloud, but seems rather to be always at a certain distance from it.

Kaemtz, in his *Lehrbuch* (1832), suggests that the rise is produced by the inrush of air toward the site of the storm, this accumulation causing the rise of the barometer as the storm nears the zenith.

Although Luke Howard had a recording barometer at work in the early part of this century, he seems to have failed to notice the phenomenon; and no one in England seems to have been aware of it until the photographic barometer was started at the Radcliffe Observatory, Oxford. Manuel Johnson, when describing the new instruments at the British Association meeting at Glasgow, in 1855, said:—

"Among the most remarkable results is a sudden rise of the barometer, amounting to 0.035 inch, and an increase of temperature of 1°, coincident with the occurrence of a thunder clap which struck one of the churches in Oxford, July 14, 1855. A similar phenomenon took place during a thunderstorm on August 23, when the rise of the barometer was still greater, amounting to 0.049 inch, though the thunder clap coincident with this rise was distant."

¹ See MONTHLY WEATHER REVIEW for 1900, Vol. XXVIII, p. 154.

² The article on thunderstorms in the MONTHLY WEATHER REVIEW for July, 1901, discusses some questions that deeply interested the late G. J. Symons, founder of the splendid system of British rainfall stations and editor of Symons' Meteorological Magazine. His successor, H. Sowerby Wallis, kindly sends us a special copy of the paper by Mr. Symons which we now reprint as it is undoubtedly but little known to our American observers, some of whom have been "discovering" facts that were known a hundred years ago. A complete review of our knowledge of thunderstorms as it stood in 1893 will be published in the last part of the Proceedings of the Meteorological Congress of Chicago. Meanwhile this memoir of Symons is exceedingly suggestive. The brontometer described therein is still in working order in London and can be purchased for \$500. If several of them could be established within 5 miles of each other they would give many of the observational data that are needed by those who wish to investigate the exact phenomena of thunderstorms, hailstorms and tornadoes. We commend it to those sections in which destruction by lightning and hail and wind is sufficient to stimulate the special study of local storms with a view to prediction and protection.—C. A.

Mr. Johnson returned to the subject in the volume of Radcliffe Observations for 1857, and gave reproductions of fourteen barograms, but the scale is so compressed (only $\frac{1}{2}$ inch per hour, and $1\frac{1}{4}$ per inch of mercury) that not much is to be learned from them beyond the fact that falls occur of 0.037 inch, 0.040 inch, and 0.046 inch, and a rise of 0.070 inch; the notes on the storms are also too vague to be useful. It may, however, be well to quote the conclusion at which Mr. Johnson arrived, viz.:—

"A comparison of these notes with the accompanying illustrations cannot, in my opinion, fail to lead to the inference that the disturbances exhibited both on the barometric and the thermometric curves (especially the former) are caused by the presence of electricity in the atmosphere, of which we had on these occasions sensible proof. But they are the more interesting, from the circumstance that similar disturbances occur not unfrequently when there has been no overt manifestation of that agency; especially during the winter months, when, according to the concurrent testimony of all observers, atmospheric electricity is most abundant."

The next observation of importance is one quoted by Le Verrier, as reported to him by the observer, M. Goullon, Curé of Saint-Ruffine (Moselle). He had two barometers, a mercurial and an aneroid. On the morning of February 5, 1866, the weather being stormy with heavy rain, wind southwest, moderate, but not squally, he had just set and read his barometers, when there was a solitary loud clap of thunder, and instantly both his barometers rose 2 millimeters (0.08 inch).

The Hon. Ralph Abercromby began studying these oscillations in 1868, and in 1875 summed up the results in the following sentences, one descriptive, the other explanatory:—

"There are two classes of storms in this country: in the one the barometer rises, in the other it falls. In the case in which it rises, the sequence of weather is somewhat as follows: After the sky has become overcast, the wind hushed to an ominous silence, and the clouds seem to have lost their motion, the barometer begins to rise suddenly. In the middle of this rise, sudden heavy rain begins. After a few minutes the rain, with or without thunder and wind, becomes a little less heavy, and the barometer sometimes falls a little. The rain then continues till the end of the squall, and as it stops the barometer returns to its original level. In Great Britain the rise rarely exceeds 0.10 inch, or lasts more than two hours. These rises are always superadded to a more general rise or fall of the barometer, due either to a cyclone or to one of the small secondaries which are formed on the side of one. During some rises the wind remains unchanged; with others there is a more or less complete rotation of the wind. In all cases the disturbance seems to be confined to the lower strata of the atmosphere."

"* * * "Since the rise is always under the visible storm, it is propagated at the same rate and in the same manner as the thunderstorm. Enough is known of the course of the latter for it to be certain that they are not propagated like waves or ripples, and hence these small barometric rises are not due to aerial waves, as has been suggested. Since their general character is the same whether there is thunder or not, it is evident that electricity, even of that intensity which is discharged disruptively, is not the cause of the rise. If we look at a squall from a distance, we always see cumulus above it, which is harder or more intense in the front than in the rear of the squall. Since cumulus is the condensed summit of an ascensional column of air, it is evident that the barometric rise takes place under an uptake of air. If we consider further that a light ascensional current would give rise simply to an overcast sky, a stronger one to rain, while a still more violent one would project the air suddenly into a region so cold and dry that the resulting electricity would be discharged disruptively as lightning, the foregoing observations show that the *greatest rise is under the greatest uptake*. Our knowledge of the mechanics of fluid motion is still too unsettled for us to say with certainty whether or not an ascensional current of air would have a reaction backward, like a jet of air issuing from an orifice."

Professor Mascart also, in 1879, expressed the opinion that electricity had nothing to do with these oscillations, but suggested quite a different explanation. Premising that they are not produced by all heavy rains, but only when heavy showers fall during bright weather, he suggested that at such times rain falls through nonsaturated air, where it would evaporate freely, and so produce a local increase of pressure which, in certain thunder rains, might amount to 2 millimeters (0.08 inch). He explained the diminution of pressure which sometimes occurs, by the reversed phenomenon; he considered that thunderstorms are formed locally, and suggested that the condensation of masses of vapor into rain drops ought to produce a diminution of pressure.

M. Teisserenc de Bort and Mr. Budd have suggested that the rise may be due to the local compression of the air by the multitude of falling rain drops.

In the *Annales* of the French Meteorological Office for 1880, M. Renou gives reproductions of some barograms from the Observatory at Parc St-Maur. A very interesting one is reproduced in fig. 1. M. Renou does not append any remarks to the plate; but from other sources it appears that there was a heavy thunderstorm from 10 till 11 p. m. on August 18, 1878. The total rise may be taken as 0.10 inch and the fall as nearly 0.15 inch.

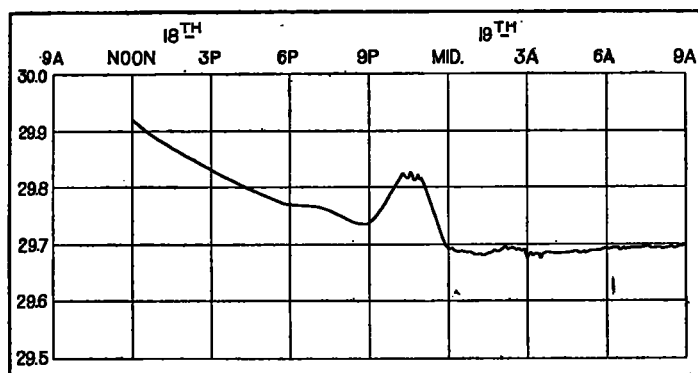


FIG. 1.—Parc St.-Maur, Paris, August, 1878.

Dr. Fines, of Perpignan, established a Redier barograph in 1875, and in a memoir published in 1883 gives reproductions of the traces during several storms. He states that, considering the present imperfect knowledge of the real conditions and origin of thunderstorms, it seems useless to try to explain records frequently influenced by very distant storms. One fact, however, is certain, that thunderstorms are accompanied by great condensation, which must cause variations in the density of the air, and therefore should affect the barometer. He gives 0.144 inch in twenty minutes as the greatest variation, but says that it rarely exceeds 2 or 3 millimeters (0.08 inch or 0.12 inch) in an hour. The only facts which are certain from the records at Perpignan are that there is usually (1) before heavy rain, decrease of pressure and temperature; (2) with the rain, sudden increase of wind, rapid rise of barometer, and fall of temperature; (3) at the end of the storm rain, reversal of the last three phenomena.

Dr. Ciro Ferrari, who has devoted great attention to the progress and character of the thunderstorms of north Italy, considers the rise due to secondaries on the skirts of cyclones.

Professor Bürnstein regards them as due to temperature changes not reaching to the upper strata of the atmosphere, in which view he has partly the support of Professor Ferrel.

Professor Klossovsky, of Odessa, says that "Every storm, whether with or without hail, is accompanied by barometric oscillation." If by this phrase he means oscillations like those observed in other parts of Europe, the phenomena must be different in southern Russia, for one of the difficulties in London, for example, is that they do not occur with *all* storms, but only with *some*.

In the *Annuaire de la Montsouris Observatory* for 1889, M. Descroix, when referring to the subject, gives a barogram for August 15, 1888, which, with the accompanying notes, is so typical that it is reproduced (reduced to the same scale as the others) in fig. 2.

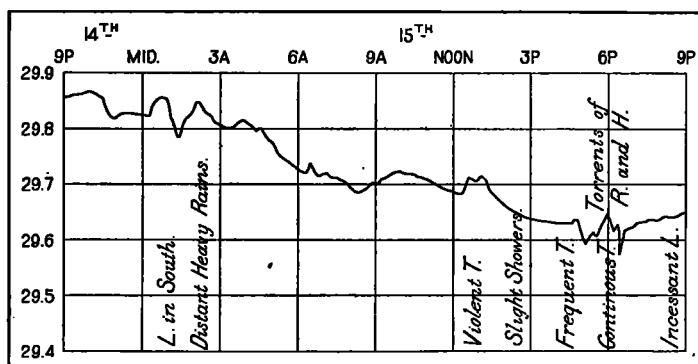


FIG. 2.—Montsouris, Paris, August, 1888.

It will be noticed that several of the opinions above quoted are contradictory, and it is not known that any one explanation is generally accepted.

The author was much struck by the remarkable curve given by his Redier barograph on the evening of August 2, 1879, and still more so when he found that the curve from a similar instrument at Messrs. Lund and Blockleys, in Pall Mall, 2½ miles south by west from his own instrument, was nearly identical (figs. 3 and 4), and he has long desired to investigate the subject. At last, in 1886, he definitely decided upon the phenomena which he considered it necessary to record mechanically. The author had read the description of Sir Francis Ronald's storm clock, and, the objects being similar, that description was useful, though the completed apparatus has scarcely one feature which even resembles Sir Francis's.

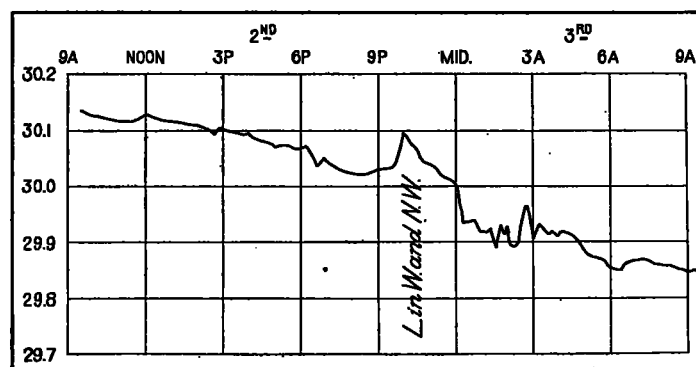


FIG. 3.—Camden Square, London, August, 1879.

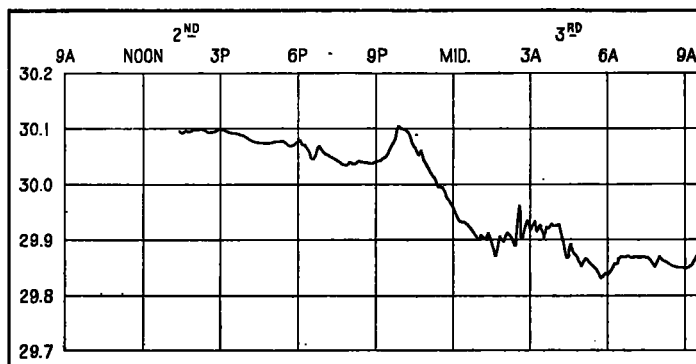


FIG. 4.—Pall Mall, London, August, 1879.

Before describing the instrument, the author considers it only fair to M.M. Richard Frères to state that not only has the apparatus been constructed, but almost wholly invented, by them. The author decided upon what the instrument was to do, and upon the scales required, but he left the whole constructional details to M.M. Richard, and considers the result a great credit to the firm.

As the primary object of the instrument¹ is the study of the phenomena of thunderstorms, it has, for brevity, been termed a brontometer, or thunderstorm measurer.

It is provided with endless paper 12 inches wide, traveling under the various recording pens at the rate of 1.2 inches per minute, or 6 feet per hour. This is about 150 times faster than is usual in meteorological instruments, and enables the time of any phenomenon to be read off with certainty to a single second of time.

The traces are made in aniline ink by a series of seven Richard pens. The first pen is driven by the clock which feeds the paper, so that the time scale and the paper must go together. The pen usually produces a straight line, which serves as the base line for all measurements, but at 55 seconds after each minute the pen begins to go, at an angle of about 45°, one-tenth of an inch to the left, and at the sixtieth second it flies back to its original position.

The second pen is driven by one of Richard's anemo-cinematographs, a name which they have given to a pattern of anemometer not yet known in England. The external portion has some resemblance to the ordinary windmill governor, but it differs from it in that the plates are curved, not flat; they are made of aluminium, and are so light that they have little momentum, and have thus a great advantage over cups, which run on for many seconds after the wind force has decreased or ceased. The fans make one revolution for each meter of wind that passes, and send an electric current to the brontometer, where it acts on an electro magnet, and tends to draw this second pen toward the left; but a train of clockwork is constantly tending to draw the pen to the right, the joint result being that the pen continuously shows, not the total motion (as is the case with most anemometers), but the actual velocity almost second by second. It does this certainly with an error of less than five seconds, for the fans will stop dead in less than that time, and the clockwork train will bring the pen from indicating a velocity of 70 miles an hour to 20 miles an hour in three seconds, and down to a dead calm in seven seconds. The trace will thus resemble that of a pressure anemometer, but with a much more open scale than was ever before available.

The third pen is actuated by a handle, and can be set at zero or at 1, 2, 3, or 4 spaces from it. The author's original idea was, partly by watching a storm rain gage, and partly by estimation, to decide on the intensity of the rain and to indicate that intensity by moving the pen

¹Other uses for it are already apparent.

farther and farther from zero as the fall becomes heavier. Experience alone will show whether that is, or is not, superior to moving it one step for each $\frac{1}{16}$ of an inch of fallen rain, which can be done by making a Crosley rain gage send a circuit into the room where the brontometer is placed, and strike a bell there. In a heavy storm there will, however, be so much for the observer to do that very probably count would be lost. It may, therefore, be necessary to make it act automatically.

The fourth pen is actuated somewhat like a piano. On the occurrence of a flash of lightning the observer presses a key, the pen travels slightly to the right and flies back to zero. Referred to the automatic time scale this gives, to a second, the time at which the key was depressed.

The fifth pen is similar, but being intended to record the thunder, the observer will continue to hold down the key until the roll is inaudible. The time of the departure of this pen from zero will evidently be later than that for the lightning by the time interval due to the distance of the flash, and possibly something may be learned from the accurate record of the duration of the thunder.

The sixth pen is similar to the third, and is intended to record the time, duration, and intensity of hail.

The seventh and last pen is devoted to an automatic record of atmospheric pressure. As the rapid motion of the paper, which is indispensable for studying the details of a thunderstorm, has enlarged the time scale more than a hundredfold, it was imperative that the barometric scale should itself be greatly enlarged. But the range of the barometer in London is more than $2\frac{1}{4}$ inches, and no enlargement less than ten times the natural (mercurial) scale would be of any use; hence a breadth of 25 inches of paper would be necessary unless some mode of shifting the indication could be devised.

Several plans were tried but finally a modification of Richard's statorope has been adopted, which is so sensitive that it will indicate the opening or shutting of a door in any part of the house, gives a scale of 30 inches for each mercurial inch (i. e., about three times that of a glycerine barometer) and yet only requires 4 inches breadth of the brontometer paper. Without entering into all the details of construction, it is desirable to explain the general principle and its application. As it was essential that the apparatus should record accurately to 0.001 inch of mercurial barometric pressure, it was evident that friction had to be reduced to a minimum, and considerable motive power provided. This is done by placing in the base of the brontometer a galvanized-iron chamber which contains about $3\frac{1}{2}$ cubic feet of air; on the upper part are a series of elastic chambers, similar to the vacuum boxes of the aneroid barometers but much larger.

When the instrument is to be put in action these chambers are connected with the large air chamber, and a tap is closed which shuts off communication with the external air. Any subsequent increase or decrease of atmospheric pressure will compress or allow to dilate the air in these chambers, and the motion of the elastic ones produces that of the recording pen.

Obviously, any large change in the temperature of the confined air would vitiate the readings; but (1) the instrument is not required to give absolute, but merely differential, values, and (2) the influence of the changes of temperature is greatly reduced by the chamber being surrounded with 4 inches thick of nonconducting material, besides nearly 1 inch of wood outside of it. The change of temperature in a room, and during the short time that the statorope will be worked without resetting to zero (i. e., without opening the tap) has not hitherto produced any measurable effect.

The author hopes, in a subsequent paper, to have the honor of laying before the society the results obtained from this novel apparatus.

APPENDIX.

List of some papers and memoirs on the subject of the paper.

Planer, J. J. Observationis Oscillationis Mercurii in Tubo Torricelliano Erfordie instituta. Acta Acad. Moguntinæ. 1782-3.

Rosenthal, G. E. Merkmale für das Herannahen d. Gewitters. Mag. Neueste Physik. Vol. 4. Part I. 1786.

Toaldo, G. Dei moti del Barometro nei Temporal. Giornale Astro-Meteorologico. 1794. (The note is dated April 3, 1795; see also his collected works—Completa Raccolta, etc. Venezia. 4 vols. 8vo. 1802. Vol. 3. P. 104, and vol. 4, p. 41).

Frenzel, F. O. Veränderung d. Barometerstandes bei Gewittern. Gren's Neues Journal der Physik. Vol. 4. 1797. P. 250.

Gronau, K. L. Ueber die Gewitter in den Gegenden von Berlin. Schweigger's Journal. Vol. 31. 1821. P. 128.

Strehlke, F. Ueber d. Einfluss d. Gewitters auf den Barometerstand. Poggendorff's Annalen. Vol. 19. 1830. P. 148.

Kaemtz, L. F. Lehrbuch der Meteorologie. Vol. 1. 1831. P. 351.

Johnson, M. J. On the Detection and Measurement of Atmospheric Electricity by the Photo-barograph and Thermograph. British Association Report. 1855. Part II. P. 40.

— Meteorological Observations made at the Radcliffe Observatory. Oxford. 1857. P. 34.

Goullon. Élévation brusque du Baromètre pendant un Coup de Tonnerre. Bulletin International. Mars 21. 1866.

Whitehouse, W. On a New Instrument for Recording Minute Variations of Atmospheric Pressure. Roy. Soc. Proc. Vol. 19. 1871. P. 491.

Abercromby, Hon. R. On the Barometric Fluctuations in Squalls and Thunderstorms. Meteor. Soc. Quart. Journ. Vol. 2. 1875. P. 450.

Fines. Courbes du Barographe Redier à Perpignan pendant les Orages des 7 et 11 Juillet, 1877. Quinzaine Météorologique. 1877. P. 66.

Mascart, E. Sur l'Inscription des Phénomènes Météorologiques, en particulier de l'Électricité et de la Pression. Journal de Physique. Vol. 8. 1879. P. 329. Annuaire de la Société Météorologique de France. Vol. 28. 1879. P. 7.

Schenzl, G. Ungewitter vom 23 Februar, 1879. Zeit. d. Oesterr. Gesells. f. Meteor. Vol. 14. 1879. P. 146.

Renou, E. [Diagrams only.] Annales du Bureau Central Météor. 1880. Part I.

Fines. Climatologie du Roussillon. Annales du Bureau Central Météorologique. 1881. Part I. B. 118.

Assmann. [Interesting reproductions of the Magdeburg barograph curves are given in the] Jahrb. der Meteor. Beob. der Wetterwarte der Magdeburgischen Zeitung. Jahr. 1-5, Magdeburg, 1883-87.

Koepen. Ueber Barometerschwankungen beim Gewitter. Tageblatt der 57 Naturforscherversammlung zu Magdeburg. 1884. P. 301.

Hellmann, G. Eine historische Bemerkung. Zeits. d. Oesterr. Gesells. f. Meteor. Vol. 19. 1884. P. 43.

Bezold, W. von. Ueber die Vertheilung des Luftdruckes und der Temperatur während grösserer Gewitter. Zeits. d. Oesterr. Gesells. f. Meteor. Vol. 19. 1884. P. 281.

Schoenrock, A. Ueber Kleine unregelmässige Schwankungen des Luftdruckes nach den Aufzeichnungen des Barographen. Zeits. d. Oesterr. Gesells. f. Meteor. Vol. 19. 1884. P. 396.

Ferrari, O. Ueber die Vertheilung des Luftdruckes und der Temperatur bei Gewittern. Zeits. d. Oesterr. Gesells. f. Meteor. Vol. 19. 1884. P. 426.

— Andamento tipico dei Registratori durante un Temporale. Annali Meteorologia Italiana. Vol. 7. 1885. Part I. P. 65.

— Ueber die Krümmung der Barometer-curve während des Gewitters. Das Wetter. Vol. I. 1885. P. 135.

Schoenrock, A. Ueber kleine unregelmässige Barometer-Schwankungen. Wild's Repertorium. Vol. 9. 1885. No. 8.

Klossovsky, A. Les Orages en Russie. Odessa. 1886.

Boernstein, R. Die Gewitter vom 13-17 Juli, 1884, in Deutschland. Zeits. f. Meteor. Vol. 22. 1887. P. 443.

Less, E. Ueber kurze Luftdruckschwankungen, welche in Begleitung starker Blitzschläge auftreten. Zeits. f. Meteor. Vol. 23. 1888. P. 151.

Desroix, L. Phénomènes accidentels * * * à Montsouris en 1888. Annales de l'Observatoire de Montsouris pour 1889. P. 195.

Ferrel, W. A Popular Treatise on the Winds. 1889.

COLORED SNOW.

A correspondent in Pawpaw, Mich., asks:

Has any one ever investigated the cause of colored snow? Almost every winter we have snowfalls that have a powdery substance that would be almost imperceptible except that it colors the snow quite materially. We had such a phenomenon last Saturday (February 16, 1901). Three years ago a very pronounced black snowfall occurred. I melted a quantity of the snow; the residue was in scaly particles, and, so far as my amateur investigation could determine, it was entirely metallic. I have some of the material from last Saturday's snowfall. It is brown instead of black, but is not yet entirely dry. It has the appearance of being vegetable matter, although the day was so calm that my windmill did not run. We used to call it prairie dust, swept off the western plains, but I am inclined to the belief that it is meteoric—star dust, if you please.

It would be interesting to know the extent of this colored snowfall, and your department, it would seem to me, is the proper one to investigate it.

This phenomenon is not an unusual one, but since none of the numerous voluntary observers in Michigan noted colored snowfall on February 16, 1901, we infer that in this case the fall was confined to a small area, perhaps embracing only two or three townships.

In the New York State Weather Service Report for April, 1889, (see also the MONTHLY WEATHER REVIEW, Vol. XVII, April 1889, p. 89,) is an account of a black snowfall "cover-